

Analysis of a Case ■

Solutions to Challenges Facing a University Digital Library and Press

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Abstract During the creation of a university digital library and press intended to serve as a medical reference and education tool for health care providers and their patients, six distinct and complex digital publishing challenges were encountered. Over nine years, through a multidisciplinary approach, solutions were devised to the challenges of digital content ownership, management, mirroring, translation, interactions with users, and archiving. The result is a unique, author-owned, internationally mirrored, university digital library and press that serves as an authoritative medical reference and education tool for users around the world. The purpose of this paper is to share the valuable digital publishing lessons learned and outline the challenges facing university digital libraries and presses.

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The creators of the Virtual Hospital® have always felt philosophically that learning is a process of lifelong apprenticeship.¹ Their vision from the start of the project in 1991 was to build an “apprentice’s assistant” in the form of a digital library filled with peer-reviewed, authoritative information for patients and health care providers, to be used as a tool for medical reference and education. Their goal was to operate the digital library as a digital press for the health sciences faculty at The University of Iowa by recruiting individual authors to create digital textbooks. The business model adopted was that The University of Iowa funds the core operating functions of this digital library and digital press by paying for the computer hardware and software and the six full-time employees needed to create and distribute these textbooks. This allows the medical information on the digital library to be distributed at no cost to users. The University’s long-term hope is that some of the operating costs of the

digital library will be recovered through the sale of continuing education credits to health care providers from continuing education courses on the digital library derived from the digital textbooks.²

The University of Iowa has clear reasons for funding the operation of a digital library and press. A university is a “knowledge factory.”³ Indeed, a university exists to create, propagate, and preserve that knowledge. Daniel Coit Gilman, the founder of the first university press at Johns Hopkins University, remarked that, “It is a university’s task to advance knowledge, and to diffuse it not merely among those who can attend the daily lectures, but far and wide.” Today, the establishment of a university digital library and press allows for the cheaper and wider dissemination of a university’s knowledge than ever before. It can thereby help a public institution such as The University of Iowa to better fulfill its three-fold mission of teaching, research, and public service to the citizens of the State of Iowa, through improved constituent outreach leading to the generation of tremendous goodwill.

The Virtual Hospital began in late 1991 as a number of digital textbooks, which in November 1992 were gathered into a digital library using Gopher on the Internet. In November 1993, the digital library was transferred to the World Wide Web (<http://www.vh.org>), becoming approximately the 250th Web

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server on the Internet.⁴ From 1994 through 1997, funding for the Virtual Hospital by the National Library of Medicine allowed for the dramatic expansion of digital library content, which continues to the present. Currently, the Virtual Hospital contains 131 digital textbooks and booklets written by 166 authors in 29 departments and four health sciences colleges at The University of Iowa. It also contains several hundred other digital textbooks and booklets written by state and national health care organizations. The majority of these digital textbooks are original works that exist only in digital form. Some of the digital textbooks are repurposed print textbooks, for which the authors were reassigned copyright by the print publishers. All the content creation and distribution services are free to authors, and all the digital textbooks are in English. The majority of content on the Virtual Hospital is peer reviewed by departmental peer-review boards. A metadata standard (e.g., Dublin Core) is not currently used by the digital library; when a content management system is installed in the future, the appropriate metadata standard will be used throughout to annotate the digital library.

The digital library is heavily used and usage is growing. Currently, the Virtual Hospital is receiving 8,000,000 hits per month, which translates to 20,000 visitors per day, with 10 percent of the visitors coming from Iowa and 25 percent coming from outside the United States. Over the past nine years, the Virtual Hospital has also had a positive influence in the domains of digital library information architecture and design, establishment of peer-review processes, and evaluation.⁵

In the nine years since the Virtual Hospital was started, six distinct and complex digital publishing challenges were encountered. Through a multidisciplinary approach, solutions were devised to these challenges in the domains of digital content ownership, management, mirroring, translation, interactions with users, and archiving. The purpose of this paper is to share the valuable digital publishing lessons that were learned and outline the challenges facing university digital libraries and presses.

Digital Publishing Lessons

Ownership

The first challenge was that of content ownership. In the university setting, ownership of intellectual property has traditionally been held by the faculty member who created the property. This is now changing at some universities which, in search of new revenue streams, are asserting that they own faculty members'

intellectual property.⁶ This issue was resolved in a progressive manner by a multidisciplinary working group composed of the Virtual Hospital's creators, the Counsel from the Office of the Vice President for Research, and the Executive Director of The University of Iowa Research Foundation, which oversees the University's intellectual property portfolio. The group created the Virtual Hospital Author's Agreement. When faculty contribute content to the Virtual Hospital, they sign this agreement with The University of Iowa. The agreement establishes that the faculty owns the copyright to the content. It also gives the university a nonexclusive right to distribute the content on the Virtual Hospital. The author is free to distribute the same content in any other way, as long as it does not prevent the content from being distributed by the Virtual Hospital. Once the author's agreement is signed, the author becomes a member of the Virtual Hospital's Content Provider Cooperative. This entitles the author to receive the majority share (90 percent) of profits when revenue is generated from the use of the content, with a small percentage (10 percent) of the profits going back to the university to fund the operation of the Virtual Hospital.

Management

The second challenge was convincing authors to continue working with the digital press and contribute more content to it in the future, rather than striking off on their own digital publishing endeavors.

The Virtual Hospital creates and nurtures a digital community of literary scholars in the following manner. The first step was obtaining a registered trademark on the brand Virtual Hospital, which is continuously policed and protected against infringement. The second step was storing the authors' content on fast, reliable, redundant Web servers that guarantee access to the authors' content nearly 100 percent of the time. The third step was undertaking extensive publicity and marketing of authors' digital textbooks when they are first published on the digital library, by indexing them in the major Internet search engines and in the major medical Web indexes. The fourth step was providing authors with monthly statistical summaries of how their content is being used (<http://support.vh.org/reports.html>) and maintaining for each digital textbook a page of feedback and comments from readers. The fifth step was sending a newsletter to authors, describing the overall use of the digital library (<http://www.vh.org/Misc/VHNewsletter/Newsletter1.html>) as well as a personalized summary of use of their digital textbooks each year.

The sixth step was encouraging authors to file for federal copyright protection for their digital textbooks and policing the Internet for evidence of copyright infringement of their materials. The final step was being responsible for rights management of the authors' content by overseeing all requests for content licensing and permissions from other print and digital publishers. The result has been the recruitment and retention of a large number of satisfied authors whose high-quality content has allowed us to create a highly regarded international brand for medical information and education.

Mirroring

The third challenge was content mirroring. The first text written about digital libraries correctly predicted that to deliver content rapidly to users around the world, content would have to be duplicated, or mirrored, in close proximity to those users.⁷ Approximately 25 percent of the Virtual Hospital's overall usage and 23 percent of its electronic mail has come from international users.^{8,9} Because international communication links are slow and expensive to use, the overall effect is to restrict international usage of digital libraries located in the United States. Therefore, the Virtual Hospital began to consider establishing mirror sites around the world, to increase international usage of the Virtual Hospital.

Initially, two informal mirror sites were established in 1996, at the Osaka Medical College in Japan and the University of Buenos Aires in Argentina. Copies of selected portions of the Virtual Hospital were pressed onto CD-ROMs and mailed to contacts at the two sites, who loaded them onto local servers. A number of serious problems were encountered immediately. Most important, by allowing the loading of the digital library onto the server of another institution, by persons with whom the Virtual Hospital had no personal relationship, the Virtual Hospital effectively lost control of its intellectual property. The Virtual Hospital could not communicate effectively with the mirror sites because of language difficulties, could not update its content on the mirror sites regularly because automated mirroring software tools did not yet exist, and could not obtain usage statistics from the mirror sites to learn how its content was being used. Also, the Virtual Hospital could not prevent the mirror sites from being indexed by Internet search engines, leading to users often finding outdated content on the mirror site before finding the current content on the main site in Iowa. Users finding such outdated content on a mirror site held the Virtual Hospital responsible, but the Virtual Hospital was unable to correct the situa-

tion. After approximately a year of operation, the informal mirror sites were discontinued in 1997.

By 1998, the Virtual Hospital had developed a technique for mirroring that has two components that allow it to retain complete control over the entire process. The first component is the Virtual Hospital Mirroring Agreement, created by The University of Iowa's Counsel to the Vice President for Research, which serves as the formal agreement between The University of Iowa and the fellow mirroring university. The mirroring agreement importantly states that the mirroring institution will guarantee the integrity of the Virtual Hospital's intellectual property. The second component is Web server appliances, which first appeared on the commercial market in 1998. These are small, low-cost (approximately \$1,000) computers that use open-source software, are dedicated to functioning solely as Web servers, and can handle heavy usage loads.

According to terms of the mirroring agreement, the Web server appliance is purchased by the mirror site, shipped to The University of Iowa, where it is loaded with a copy of the Virtual Hospital, and then shipped back to the mirror site. At the mirror site the Web server appliance is plugged into the Internet and into an electrical outlet, and the Virtual Hospital is notified. At that point, the Virtual Hospital assumes full responsibility for the operation of the Web server appliance and administers the Web server appliance remotely across the Internet. Personnel at the mirror site are not given password access to the Web server appliance. The content on the mirror site is updated daily using the recently developed automated mirroring software tool *rsync* (Andrew Tridgell, Macgregor, Australia; rsync.samba.org). Use of this mirroring technique, which requires minimal staff effort, overcomes all the previously encountered mirroring problems by allowing the Virtual Hospital to retain complete control of its intellectual property. The Virtual Hospital has access to all mirror site usage statistics to allow it to learn how its content is being used, and the Virtual Hospital is able to prevent the indexing of mirror sites by Internet search engines.

The results have been spectacular. The first mirror sites became operational early in 1999 at the University of Queensland in Australia and at National Taiwan University in Taiwan. Mirrors will be installed in the near future at Cambridge University in England, the University of Iceland in Iceland, and the University of the Andes in Venezuela. Server log file analysis of the mirror sites shows an increase in local as well as regional usage of the mirror sites, and mirror site usage is growing steadily over time. Thus, the instal-

lation of these mirror sites around the world has led to lower costs and speedier access for international users, thus lowering another barrier to information access and leading to increased international usage of the Virtual Hospital.

This low-cost mirroring solution can be used by third-world countries that have an acute need for authoritative medical information but lack the money for print journal subscriptions.¹⁰ If Internet access and such mirror sites can be established in these countries, they will benefit from free access to university digital libraries as well as other authoritative Internet medical resources, such as online journals. Perhaps in the future, international professional societies can play a role in helping fund the installation and support of mirror sites in such countries and the subscription costs for online journals.

Translation

The fourth challenge was content translation. As American culture is increasing its worldwide influence via trade, television, and movies, it is natural to ask whether English will be the language of the Internet and whether translation will be necessary. Unfortunately, people use English as a second language with varying facility. For in-depth communication, people naturally fall back on their native language. Furthermore, studies now predict that, by the year 2000, U.S. users will account for less than 50 percent of all Internet users and that, by 2003, less than 50 percent of all Internet users will be primary English speakers. These trends are similar to those of short-wave radio broadcasting at the British Broadcasting Corporation's (BBC) World Service. Believing when it began in 1932 that there was a thirst for authoritative, current information throughout the world on all subjects, the BBC began by broadcasting to the world solely in English. Over time, the BBC learned that information needs to be broadcast in native languages to reach most people. Accordingly, by 1992 the BBC was broadcasting to the world in 37 languages.¹¹ In a similar manner, the Virtual Hospital felt it would receive more international usage if it had more translated information available.

Therefore, the Virtual Hospital began to explore machine translation for on-the-fly, immediate translation of information. Machine translation, which is the automated translation by a computer from one written language to another without human oversight and intervention, goes back 50 years.¹² Although it has had lofty goals, promising quick and cheap translation, it has distinct problems. To be effective, the translated text must initially be in grammatically correct form

and cannot include colloquialisms. Because of this, only 60 to 70 percent accuracy is claimed by vendors. The Virtual Hospital seriously considered placing links at the bottom of every page on the digital library, with an appropriate disclaimer, to enable digital library users to conveniently obtain machine-translated versions of each page, using the AltaVista Babelfish machine translation software (AltaVista, Palo Alto, California; babelfish.altavista.com) which is developed by Systran (Systran, Soisy-sous-Montmorency, France; www.systransoft.com). Unfortunately, recent studies of machine translation on medical information by the World Health Organization (WHO) found that translations of medical content by similar machine translation software were unacceptably inaccurate and imprecise and, furthermore, that the translations produced by it were acceptable only if they were subsequently revised by human translators.¹³ Therefore, the Virtual Hospital does not make machine translation conveniently available to its users, since it did not feel comfortable endorsing a system with such high inaccuracy and imprecision.

The Virtual Hospital then researched the cost of manual translation of information, which, although being slow, is of the highest quality. Unfortunately, it is also extremely expensive. For example, The University of Iowa Translation Laboratory quoted a price of \$1,200 to translate a small 10-page digital booklet on total hip replacement (<http://www.vh.org/Patients/IHB/Ortho/HipReplace/HipReplace.html>) from English into Spanish. The Virtual Hospital is therefore asking its partners in digital library mirroring to undertake the voluntary translation of some of the most popular content in the digital library, as part of their mirroring collaboration with the Virtual Hospital. The Virtual Hospital also hopes to interest international professional societies in the translation of such popular digital library content.

Interactions With Users

A completely unexpected challenge faced by the Virtual Hospital was user-initiated dialogue with the digital library's creators and authors. The digital library began to receive an average of ten daily unsolicited e-mail "cries for help" from patients around the world.⁹ Unsolicited e-mail is e-mail sent to an author from a person unknown to the author who is seeking professional help. From 1992 to 1997, the Virtual Hospital did not reply to any of the unsolicited e-mails. In January 1998, a short reply was developed, which was a simple disclaimer statement. On further reflection, however, the Virtual Hospital staff felt the need to do more to help the users who send unsolicited e-mail. Accordingly, in April 1998, with the assistance

of the Counsel to the Vice President for Research, the Virtual Hospital developed a standardized reply that is automatically delivered to each sender of unsolicited e-mail. The reply, which is meant to be both helpful and medicolegally responsible, refers senders to quality information resources that may be of further assistance to them.¹⁴

Archiving

The final challenge faced by the Virtual Hospital was to preserve for posterity the information in the digital library, which exists exclusively in digital form. A great library has always been a monument to permanence. Unfortunately, the history of libraries repeats itself, in that over time great libraries have been built, only to then disappear because of war, religion, changes in government, or neglect.¹⁵ There is concern that the same fate could befall digital libraries on the Internet.^{16,17} The challenge of archiving digital libraries involves three questions. First, in the growing sea of information that is the Internet, what information should be archived and preserved? Certainly, all information is not of equal value, yet if selective archiving is done, how can one predict today what information will be needed in the future? Second, how should the information be archived? Should the information be preserved in its native file format on its native media, along with the machines that created it, or should the information be translated to new file formats and new media as they evolve over time? Third are the legal and ethical implications of archiving. Is archiving information a violation of copyright law as well as an individual's privacy?

Today, the implications and ramifications of archiving information on the Internet are still not fully understood. Nonetheless, The Internet Archive (Internet Archive, San Francisco, California; www.archive.org), a nonprofit trust dedicated to preserving the World Wide Web for future generations, has begun archiving the publicly accessible Internet.^{16,17} The Internet Archive, which is funded by a number of Internet cognoscenti, has pledged to copy its data to new file formats and new media every ten years and, most importantly, regularly donate a copy of its data to the Library of Congress, which should help ensure the longevity of its dataset. While it currently has no peers and is a solid start towards archiving the Internet, The Internet Archive unfortunately cannot currently archive the significant number of Web sites that require registration or that are dynamically generated by databases. To archive a publicly accessible digital library in The Internet Archive, one merely visits their Web page (http://www.archive.org/get_archived.html) and types in the address of the digital library

to be archived. The Virtual Hospital has been regularly archived by The Internet Archive since 1997.

Governments, professional societies, and universities will also play a key role in archiving digital libraries. To date, the most successful digital archive in the sciences is the Los Alamos National Laboratory E-print Archive (<http://xxx.lanl.gov>). This archive, begun in 1991, currently archives all versions of an article, from the pre-print to the final peer-reviewed version, in the fields of physics, mathematics, nonlinear sciences, and computer science, and it has become the primary forum for the dissemination of research results in these fields. Similar initiatives are in their formative stages in the biomedical field. The National Institutes of Health are creating PubMed Central (<http://www.pubmedcentral.nih.gov>), which is intended to serve as a Web-based repository and archive for barrier-free access to primary reports in the life sciences. NetPrints (<http://clinmed.netprints.org>) is a collaboration between the British Medical Association's publishing group and the Stanford University Library HighWire Press and is intended to be an electronic archive where authors can post their research into clinical medicine and health before, during, or after peer review. BioOne (<http://www.bioone.org>) is a collaboration being developed between professional societies, academia, the Scholarly Publishing and Academic Resources Coalition (SPARC), and the commercial sector to bring an archive of high-impact life science journals to the Internet. These initiatives, which are under constant revision, are at the intersection of new ways of publishing and archiving, and their success will ultimately depend on their ability to form successful relationships with the publishers. In the history of library archiving, great libraries that suffer calamitous losses usually have their collections reconstituted by individuals.¹⁵ It remains to be seen whether the future will be any different from the past in this regard.

Future

Further Applications of Lessons Learned

The generalizability of the digital publishing lessons learned by the Virtual Hospital is demonstrated by the fact that since completion of the National Library of Medicine's funding of the Virtual Hospital in December 1997, many of the creators of the Virtual Hospital have gone on to start new cutting-edge digital library projects and have applied the digital publishing lessons learned in this project to their new ones. The University of Iowa assumed funding of the digital library in January 1998 because of its perceived high

value to the University as a digital library and press, thereby making it a sustainable program. The University requested the creation of the Virtual Children's Hospital® (<http://vch.vh.org>), to serve as an integrated interface to all the pediatric information in the Virtual Hospital, thus making it easier and clearer for health care providers, their patients, and patients' families to access that information. Analysis has shown that the creation of the Virtual Children's Hospital has fulfilled its mission.¹⁸

In 1996, the United States Navy asked the Virtual Hospital team to leverage their digital library experience to create a digital library designed to meet the information needs of naval primary care providers and their patients in isolated operational settings. The result is the Virtual Naval Hospital (<http://www.vnh.org>), a highly successful digital library used by every U.S. Navy primary care provider around the world—at sea, under the sea, and in the field. By extensive use of user-centered design principles, a problem-based interface to the digital library was created, which allows users to shift their Internet usage paradigm from one of Web surfing to one of problem solving.^{19,20}

MedicalStudent.com (<http://www.medicalstudent.com>) is a digital library whose key feature has been its role setting initial standards for digital bibliography on the Web. Designed originally to be used by medical students, MedicalStudent.com has evolved into a digital library useful to all students of medicine. Pediatric Radiology.com (<http://www.pediatricradiology.com>) and GeneralPediatrics.com (<http://www.generalpediatrics.com>) are digital libraries whose creation is being funded by the Radiological Society of North America and the Robert Wood Johnson Foundation, respectively. These two projects are currently researching techniques for the creation and use of intelligent software agents to perform automated curation of digital libraries.²¹ Finally, the Radiologic Pathology Department of the Armed Forces Institute of Pathology is undertaking the development of a large digital library and image database of radiologic and pathologic images and information (<http://www.radpath.org>).

The further generalizability of these digital publishing lessons is evidenced by the establishment of a number of university digital libraries and presses in academic medical centers over the last nine years.²² All of these have been modeled at least in part on the Virtual Hospital, as they all serve as medical reference and education tools for health care providers and their patients and have their content contributed by local health sciences faculty.

Challenges for the Virtual Hospital

The original dream for the Virtual Hospital envisioned that the digital library would be delivered to the point of care, where medical information is most acutely needed and where it would help the physician rapidly find succinct answers to the questions raised during a patient care encounter. These answers could be used to directly affect the encounter and would, ideally, help improve patient outcomes. For their brief use of the digital library, physicians would receive continuing medical education (CME) credits in small fractions, or granules, which would accumulate over time in a system termed "granular CME."

Although the Virtual Hospital has fulfilled a significant portion of the original dream, to complete the dream two more elements must fall into place. First, computers must become a ubiquitous part of physician's daily lives. This will happen once patient information is stored in electronic medical record systems and physicians have access to such systems by wireless computer networks and hand-held computers that can be carried in their pockets. Second, the acquisition of CME, delivered from digital libraries transparently linked to the electronic medical record, must be connected to the clinical encounter at the point of care, where it has the greatest potential to positively affect patient care, rather than being separated from the clinical encounter in a lecture hall. There is a growing educational consensus that CME delivered in such a clinical context should be more effective in changing physician's short- and long-term knowledge, attitudes, and behaviors and thereby positively affecting patient outcomes.²³ Accordingly, the Virtual Hospital team's current research is focused on development of the granular CME system, its delivery to the point of care, and its seamless integration into physicians' workflow.

Challenges for University Digital Libraries and Presses

University digital libraries are facing strong and extremely well-funded competition with the recent rise of well-capitalized commercial digital libraries on the Internet, such as DrKoop.com (www.drkoop.com), Medscape (www.medscape.com), and WebMD (www.webmd.com). These for-profit digital libraries offer traditional digital library medical reference and medical education services as well as additional services such as disease-specific chat forums, personal electronic medical records, and online pharmaceutical and medical supply ordering. Other competition comes from the recent appearance of many traditional print journals in commercial digital libraries published pri-

marily by large commercial publishers with some smaller university consortia. Additional competition is coming from professional societies and government organizations, which are placing their health care provider and patient information into nonprofit digital libraries that are similar in philosophy and operation to university digital libraries. While the budget of the Virtual Hospital is approximately \$300,000 a year, the market capitalization of these commercial firms is in the tens of millions to billions of dollars. The question then becomes whether there is any role for university digital libraries to play in this new medical information economy, or will the for-profit digital libraries make the presence of the university digital libraries superfluous.

University digital libraries possess four key features, only one or two of which most for-profit digital libraries possess, given that they are commercial enterprises; this will ensure the ongoing importance of university digital libraries, guaranteeing their use in the future. First, university digital libraries are free, are open to all regardless of profession, and do not require passwords or registration for their use. This gives them significantly lower barriers to access for users than the for-profit digital libraries, which either charge subscription fees, limit usage to accredited professionals, or use passwords to keep track of their users for their advertisers. An additional advantage of the free and open use of university digital libraries is that by not using passwords or requiring registration, an individual's usage of the digital library remains anonymous, thus guaranteeing patron privacy. Second, university digital libraries emphasize primarily the provision of information for health care providers, as well as information for patients.²² On the Virtual Hospital, the five most popular digital textbooks are on family medicine, dermatology, lung tumors, anatomy, and anatomic variations. The largest for-profit digital libraries, such as DrKoop.com, emphasize primarily the provision of information for patients, which is a much larger target population. Third, university digital libraries have a demonstrated commitment to publishing complete medical reference and education textbooks, as well as shorter booklets and articles. Finally, and most important, university digital libraries are free from the pressures from advertisers that the for-profit digital libraries must face. Recently, for-profit digital libraries have come under increased scrutiny, and their ethics have been viewed with skepticism as the lines between their editorial and advertising content become increasingly blurred.²⁴

Therefore, in addition to the for-profit digital libraries, the world needs university digital libraries charged with the responsibility to provide a service indepen-

dent of commercial indulgence—one that puts the needs of its users and the public interest above all else. Over the last century in broadcasting, public service broadcasters such as the British Broadcasting Corporation, National Public Radio, the Public Broadcasting Service, and C-SPAN have played such a key role. Likewise, publicly funded university digital libraries are uniquely able to put all their energies into delivering information to users, rather than users to advertisers. A university digital library's duty to inform, educate, and entertain without commercial bias becomes more, not less, important with the rise of these commercial services.

Challenges for the National Library of Medicine

The print literature is becoming increasingly irrelevant to the daily practice of medicine. Numerous studies document how physicians do not use the print literature to help in the care of their patients.²⁵ Other studies show that when physicians seek information, they seek the most convenient, not the most authoritative, resource.²⁶ Undoubtedly, patients will demonstrate similar behavior. Given that there are more patients than health care providers, that the most convenient medical information resource is now the Internet, and that more and more medical information is published on it every day, it follows that most medical information consumed by patients today is on the Internet. Michael Lesk, PhD, Division Director of Information and Intelligent Systems at the National Science Foundation, states that, "for every person entering a physical library today, 20 use a search engine."²⁷

The traditional functions of a librarian have been to select the material users require, to catalog the material so that those who would use it know what is available and where it is kept, to preserve the material so that both contemporary and future readers will be able to use it, and to help users choose the materials most appropriate to their needs.¹⁵ In this new digital age, the importance of such traditional library functions is even greater.

With the advent of each major change in the history of medical publishing, medical bibliography has struggled to keep up with increases in the size of the medical literature. Nonetheless, in each transition, from papyrus scrolls and illuminated manuscripts to printed manuscripts and the post-World War II scientific literature explosion, librarians have eventually developed new bibliographic tools and techniques to keep up with the medical literature.²⁸

Therefore, to stay relevant to the practice of medicine, the National Library of Medicine needs to begin to systematically catalog, collect, and preserve the best

of the digital medical literature, in the same manner that it now does the print literature. To do this, it must first define a medical metadata standard, derived from the Dublin Core Metadata standard, and encourage the use of such a standard by digital medical publishers. It must then go on to set standards for defining what is authoritative digital medical literature and undertake the indexing of such literature in a MEDLINE-like index—a “WEBLINE.” Finally, to ensure preservation of this authoritative digital medical literature for the future, it must create an archive of this authoritative digital medical literature and commit itself to preserving the archive in perpetuity.

Conclusion

When the creators of the Virtual Hospital embarked on their journey to build a digital library and press in 1991, they thought, mistakenly, that it would be a simple and straightforward task. They had never heard of the term “digital publishing.” They therefore created a simple digital library system that allowed them to achieve their mission. Along the way, a number of complex digital publishing challenges arose from this simple system, which the Virtual Hospital team successfully solved by use of a multidisciplinary approach and hard work. The result is a unique, author-owned, internationally mirrored university digital library and press that serves as an authoritative medical reference and education tool for users around the world.

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